What Human Exposure Data and Models are Available?

Halûk Özkaynak, Janet Burke, Stephen Graham

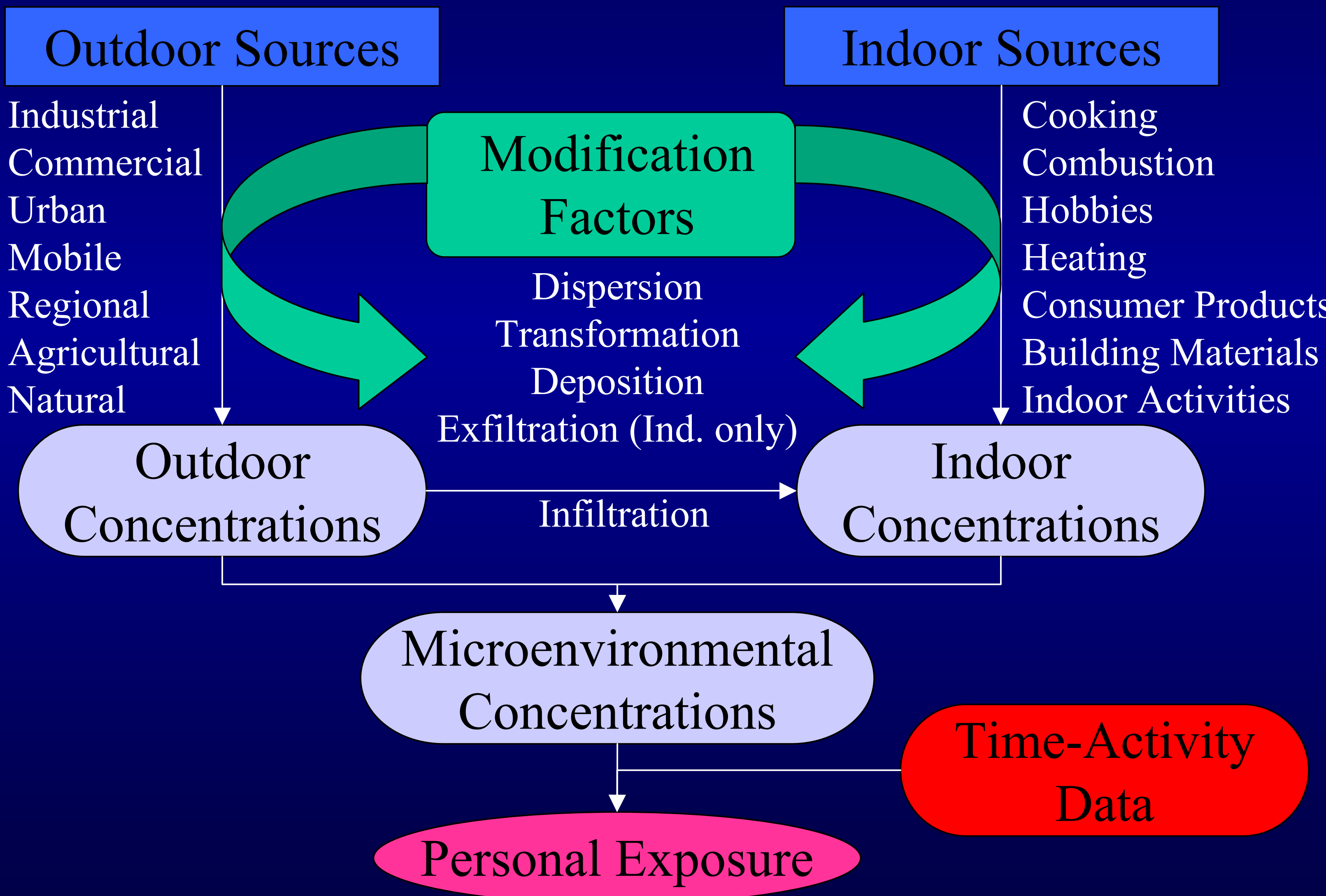
US EPA National Exposure Research Laboratory

Research Triangle Park, North Carolina

Air Toxics Exposure Modeling

Source and Exposure Overview

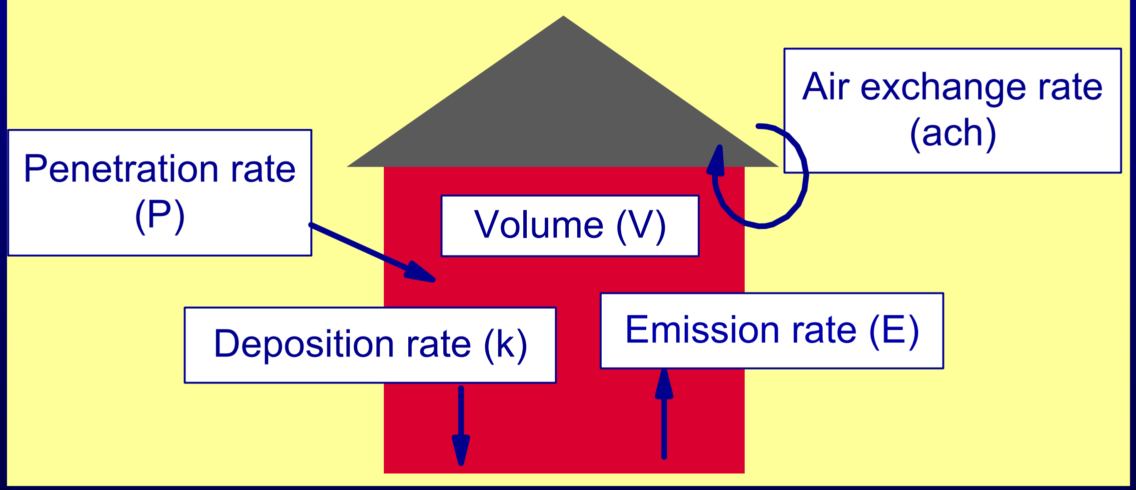
Air Toxics Exposure Modeling Concepts



Air Toxics Exposure Modeling Approaches

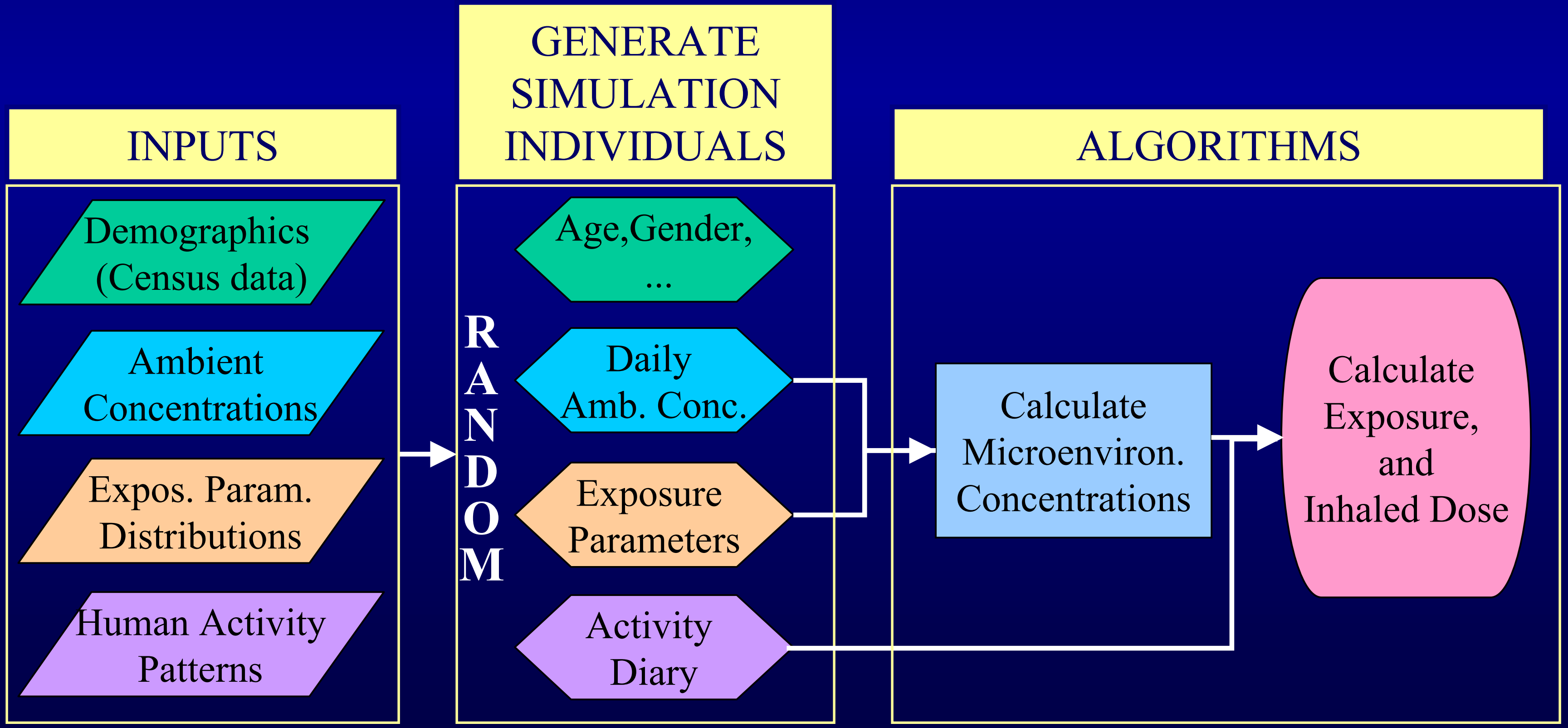
- Statistical models based on empirical data obtained from personal monitoring studies
- Deterministic models based on known or assumed physical relationships
  - e.g.

$$C_{in} = \left(C_{out} * \frac{P * ach}{ach + k} \right) + \frac{E_{smk} * N_{cig} + E_{cook} * T_{cook} + t * E_{oth}}{(ach + k) * V * t}$$



Air Toxics Exposure Modeling Approaches

- Physical-stochastic models that include Monte Carlo or other techniques to explicitly address *variability* [and in some models, *uncertainty*] in model structure/inputs



Air Toxics Exposure Modeling
Methodology

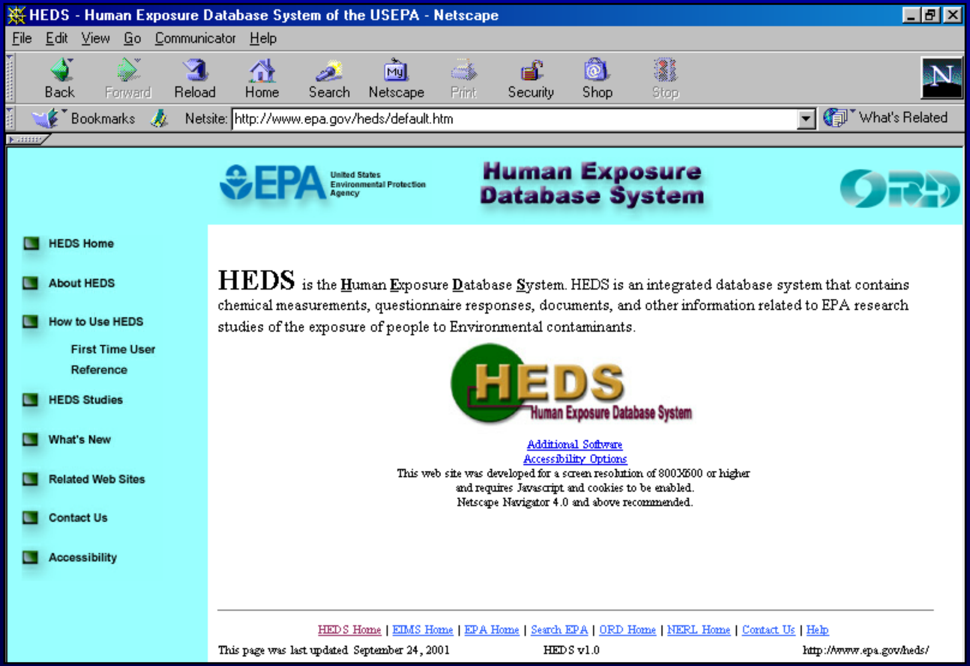
- Total personal exposure (E) is the time-weighted sum of all exposures from the different microenvironments in which a person spends time:

$$E = \frac{1}{T}\left(\sum_{j} \overline{C_j}\, t_j \right)$$

- Methodology is similar across EPA exposure models
  - Hazardous Air Pollutant Exposure Model (**HAPEM4**)
  - Air Pollutants Exposure (**APEX3**)/Total Risk Integrated Methodology (**TRiM**)
  - Stochastic Human Exposure and Dose Simulation (**SHEDS**)

Air Toxics Exposure Modeling
Exposure Database

- US EPA Human Exposure Database System (HEDS)
  - http://www.epa.gov/heds/
  - National Human Exposure Assessment Survey (NHEXAS)
  - Study Areas
    - Arizona, Maryland, and Region V
  - Chemicals
    - PAHs, VOCs, PM metals, pesticides
  - Media
    - air, water, dust, soil, dermal wipes, food
    - blood, urine, hair
  - Activity diary and housing data

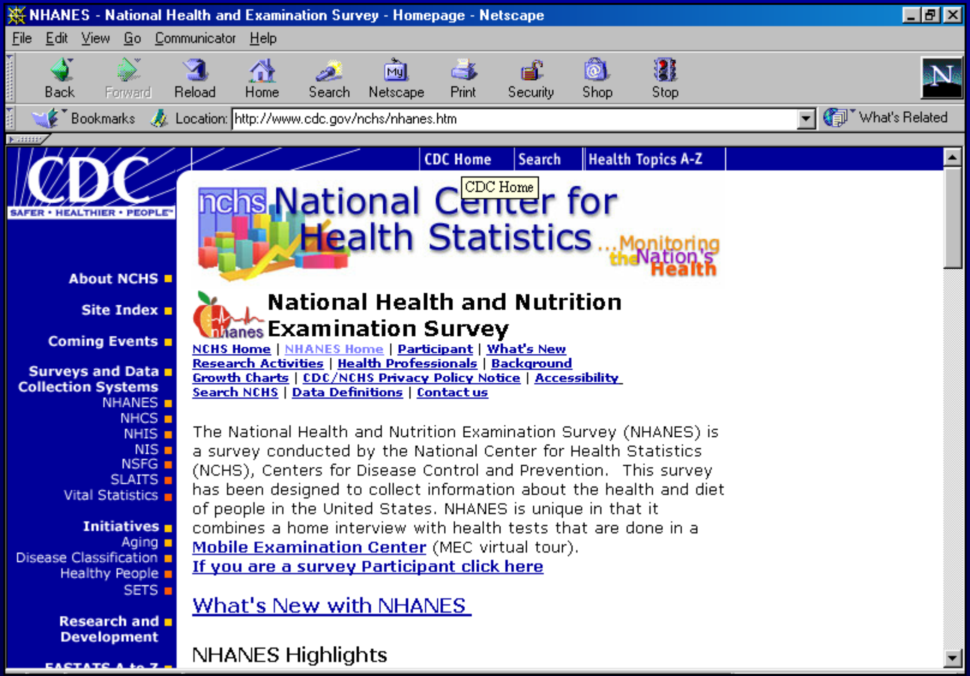


Air Toxics Exposure Modeling
Exposure Database

- **Mickey Leland National Urban Air Toxics Research Center (NUATRC)**
  - http://www.sph.uth.tmc.edu/mleland/
  - Relationship among Indoor, Outdoor, and Personal Air **(RIOPA)**
  - Study Areas
    - Los Angeles CA, Houston TX, Elizabeth NJ
  - Chemicals
    - PAHs, VOCs, PM, carbonyls, metals
  - Media
    - air

Air Toxics Exposure Modeling
Biomonitoring Database

- **National Health and Nutrition Examination Survey (NHANES)**
  - http://www.cdc.gov/nchs/nhanes.htm
  - Study Areas
    - US population-based
  - Chemicals
    - metals, cotinine (ETS), OP pesticide and phthalate metabolites
  - Media
    - blood, hair
  - Dietary Surveys



Air Toxics Exposure Modeling
Air Quality Database

- US EPA Aerometric Information Retrieval System (AIRS)
  - http://www.epa.gov/airs/
  - Study Areas
    - Nationwide
  - Chemicals
    - Criteria Pollutants, HAPS, PAMS
  - Media
    - air

Air Toxics Exposure Modeling
Air Quality Models

- **US EPA Models-3/CMAQ**
- **Urban plume:** ISCST, ISCLT, ASPEN, ARMOD
- **Roadway:** CALINE3/4, CAL3HQC

Air Toxics Exposure Modeling

Human Activity Database

- US EPA Consolidated Human Activity Database (CHAD)
  - http://www.epa.gov/chadnet1/
  - Studies
    - NHAPS, UMich, and others
  - 22,000+ person-days of 24-h activity diaries
  - Contains algorithms for estimating energy expenditure based on activity level

Air Toxics Exposure Modeling

Exposure Modeling and Results

- US EPA OAQPS National Air Toxics Assessment (NATA)
  - http://www.epa.gov/ttn/atw/nata/
  - Study Area
    - US Population
  - Chemicals
    - 33 air toxics
  - Data and Models
    - Emissions
    - Ambient concentrations from ASPEN model
    - Pop. exposure estimates from HAPEM model
    - Risk estimates

Air Toxics Exposure Modeling
NERL Research Goals

- Provide new human exposure and dose estimation models for assessing population health risks
  - **e.g. SHEDS, ERDEM**
- Address exposures of susceptible populations
- Explicitly quantify variability and uncertainty
- Develop framework that can accommodate both aggregate and cumulative exposures
- Support and enhance science conducted by program offices (e.g. OAQPS, OPPTS, OTAQ, ORIA)

Air Toxics Exposure Modeling
NERL Research Plans

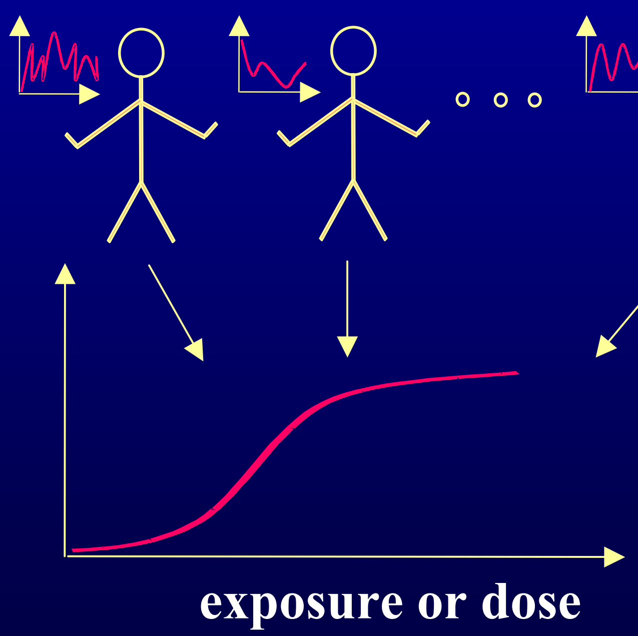
FY02	Produce multiyear research plan (peer-reviewed) for Air Toxics exposure measurements and modeling
FY03	Develop a stochastic aggregate population exposure model for Air Toxics (SHEDS), using **benzene** as a case study
FY05	Extend model to additional Air Toxics highly ranked by OAQPS, OTAQ, ORIA (formaldehyde, acetaldehyde, 1,3-butadiene, acrolein, perchloroethylene)
FY08	Develop a cumulative population exposure model for a representative set of Air Toxics

Air Toxics Exposure Modeling

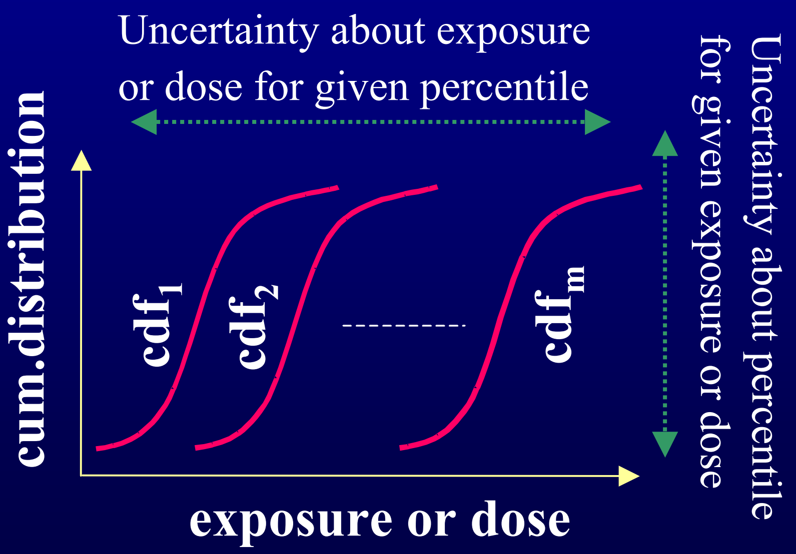
SHEDS: Variability vs Uncertainty

- **Variability:** temporal, spatial, or interindividual differences in the value of an input
- **Uncertainty:** measure of the incompleteness of knowledge/information about an unknown quantity

<u>**1-Stage Monte Carlo**</u>

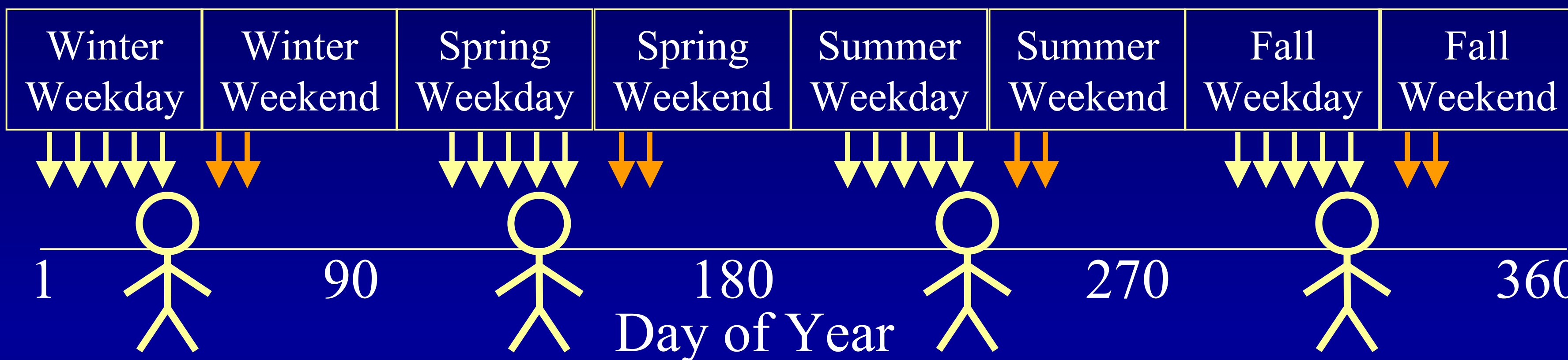


<u>**2-Stage Monte Carlo**</u>



Air Toxics Exposure Modeling

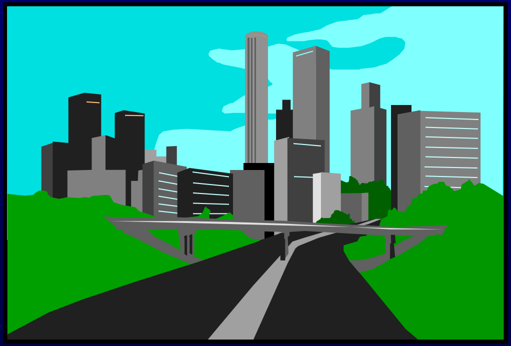
SHEDS: Longitudinal Exposure



- ~ 6-10 age-gender cohorts (~200 CHAD people/cohort)
- 8 CHAD diaries simulate a person's year in cohort
  - 1 person from each of 4 seasons
  - 1 person from each of 2 day categories (weekend and weekday)
- Fix 5 weekday diaries and 2 weekend diaries
- Repeat 7 day activity patterns within each season

Air Toxics Exposure Modeling
Commuting Algorithm

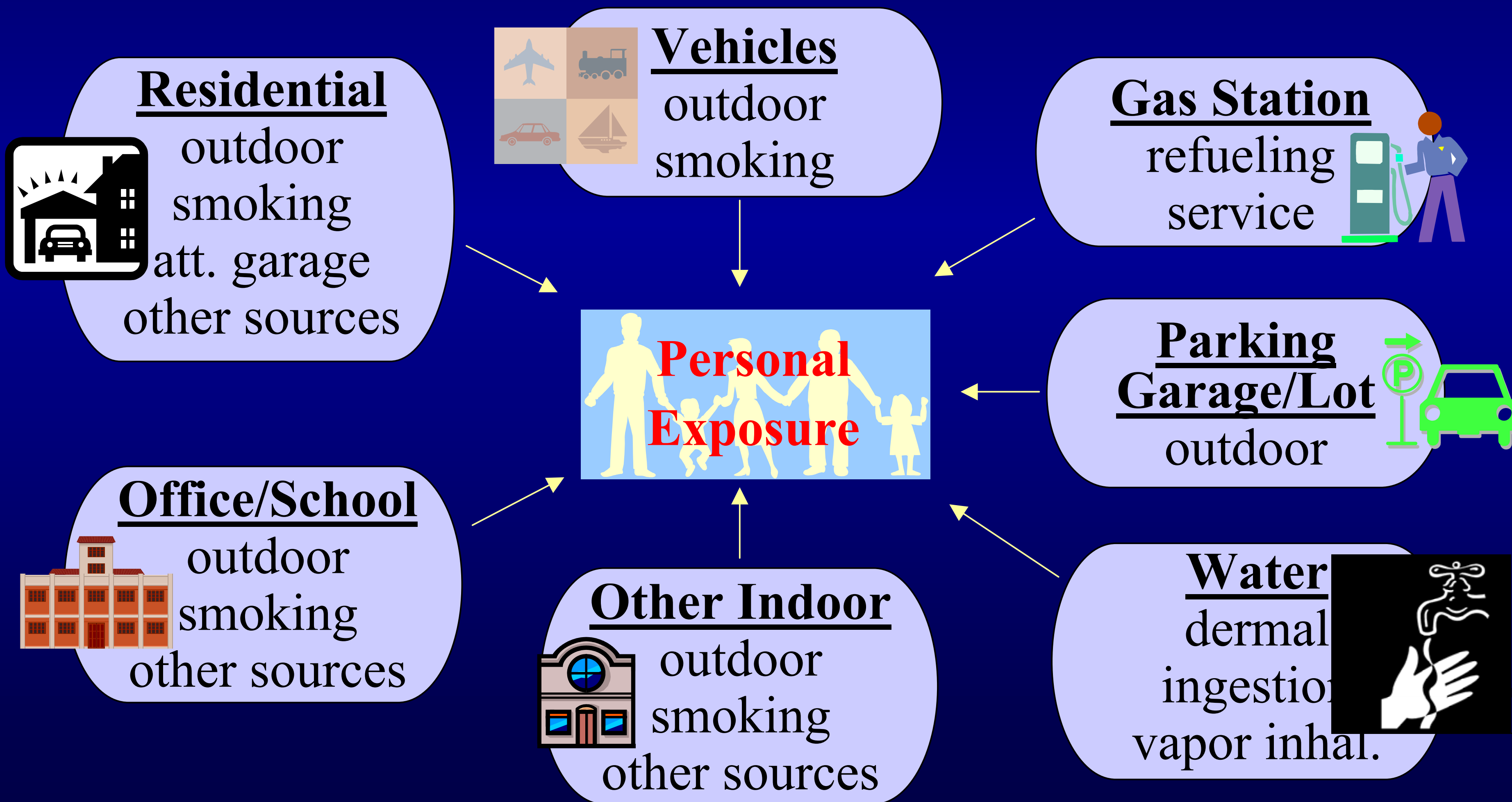
- Provides probabilities for Work Location (census tract) based on Home Location (census tract)
- National commuting flow database developed for HAPEM and APEX3 and will be utilized in SHEDS for Air Toxics
- Based on 1994 commuting flow database
- Mapped onto census tracts for Census 2000



Air Toxics Exposure Modeling

Benzene Case Study Framework

- **Exposure microenvironments and influential factors**



Air Toxics Exposure Modeling
In-Vehicle Exposure

- In-vehicle exposure is a function of roadway benzene concentrations that result primarily from gasoline powered vehicle emissions
- Several US studies characterized in-auto benzene concentrations (e.g. Chan *et al*., 1991; Weisel *et al*., 1992; Lawryk *et al*., 1995; Rodes *et al*., 1998)
  - most significant factor influencing exposure is roadway type
    - e.g., urban, highway, or rural
  - marginal exposure influence
    - time of day (i.e., rush vs. non-rush)
    - meteorological conditions (e.g., wind)
    - ventilation configuration (e.g. AC, open windows)
    - seasonal effects

Air Toxics Exposure Modeling
In-Auto Exposure Approach

- Chan *et al.* (1991) described a simple linear regression (LR) for NC highways:

  [In-Auto] = 7.9 + 1.6 * [Ambient]

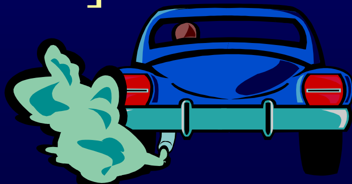
- Using data from Rodes *et al.* (1998), a similar LR for CA freeway and arterial roads:

  [In-Auto] = 9.9 (±1.0) + 1.0 (±0.23) * [Ambient]

- Since roadway concentrations are a function of vehicle emissions, a multiple linear regression of Rodes *et al.* (1998) data is proposed:

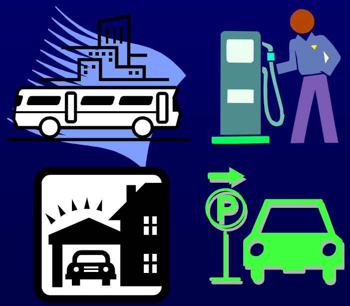
  [In-Auto] = 1.6 (±0.9) * VPH + 1.2 (±0.24) * [Ambient]

  - where VPH is thousands of vehicles per hour



Air Toxics Exposure Modeling
Other ME Approaches

- Multiplication Factors
  - Other Vehicles: factor of in-auto exposure {sev. studies}
    - Bus (0.65), Train (0.25), Motorcycle (1.4)
  - Parking Garage 2 to 7 * [ambient] {one study}
  - Gas Station 5 * [ambient] {two studies}
  - Near Street/Sidewalk 1 to 3 * [ambient] {three studies}
- Concentration distributions
  - Refueling 1,000 µg/m3 {sev. studies}
- Mass Balance
  - Residential and Attached Garage
  - Cigarette Smoking



Air Toxics Exposure Modeling
Research Needs

- Determine MEs and population groups of concern
- Measure or estimate ME factors and concentrations in important MEs with limited data or greatest uncertainty
- Measure exposures for individuals/cohorts that have limited existing data
- Develop mechanistic and stochastic models required to predict source-to-dose relationships
- Develop new data and modeling methods to address high end exposures to urban air toxics ("hot-spots")